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Arora et al.

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(54) **CONTROLLING ENERGY CONSUMPTION OF AN ELECTRONIC DEVICE IN RESPONSE TO AVAILABILITY OF AN ENERGY SOURCE**

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G06F 1/32 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 1/3212*** (2013.01); ***G06F 1/3296*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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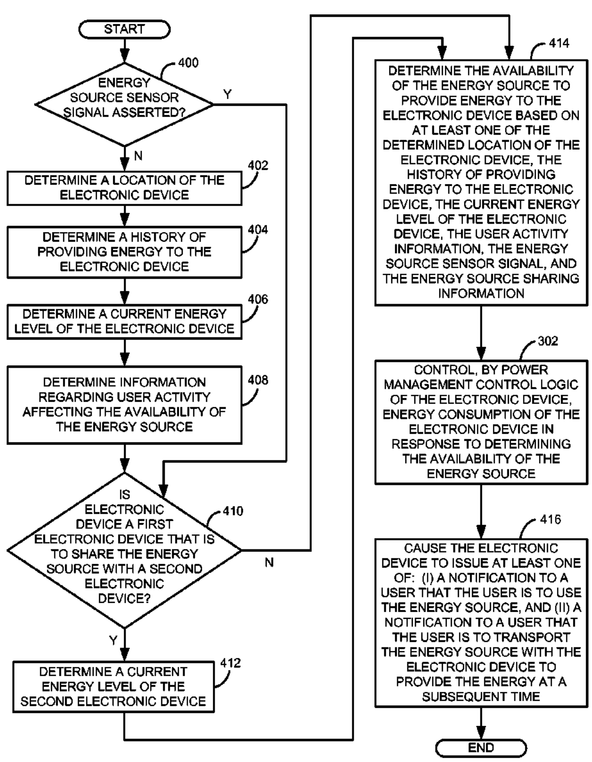
(57) **ABSTRACT**

An apparatus and methods for controlling energy consumption of an electronic device determine an availability of an energy source to provide energy to the electronic device. The apparatus and methods control, by power management control logic of the electronic device, energy consumption of the electronic device in response to determining the availability of the energy source.

19 Claims, 5 Drawing Sheets



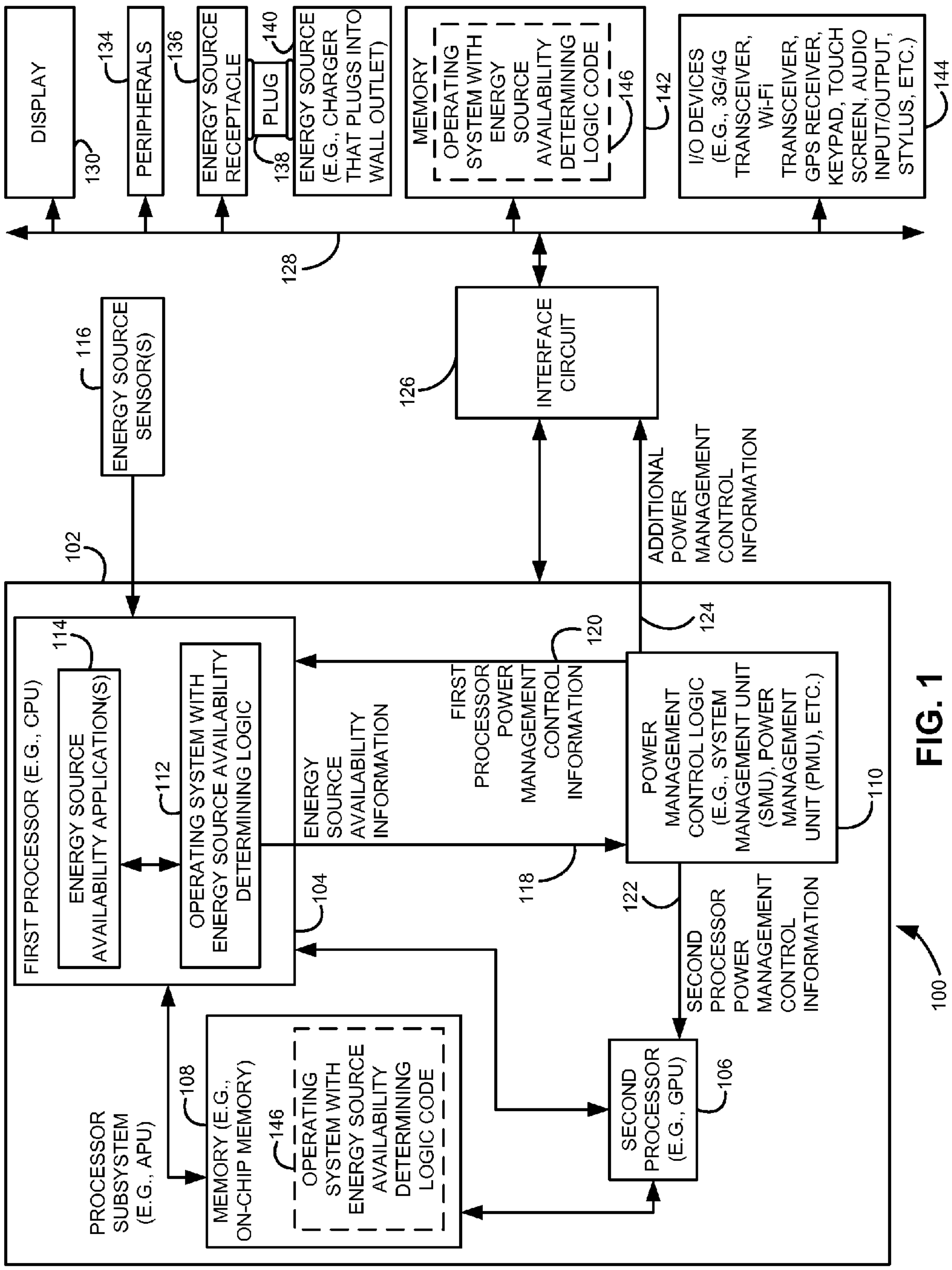
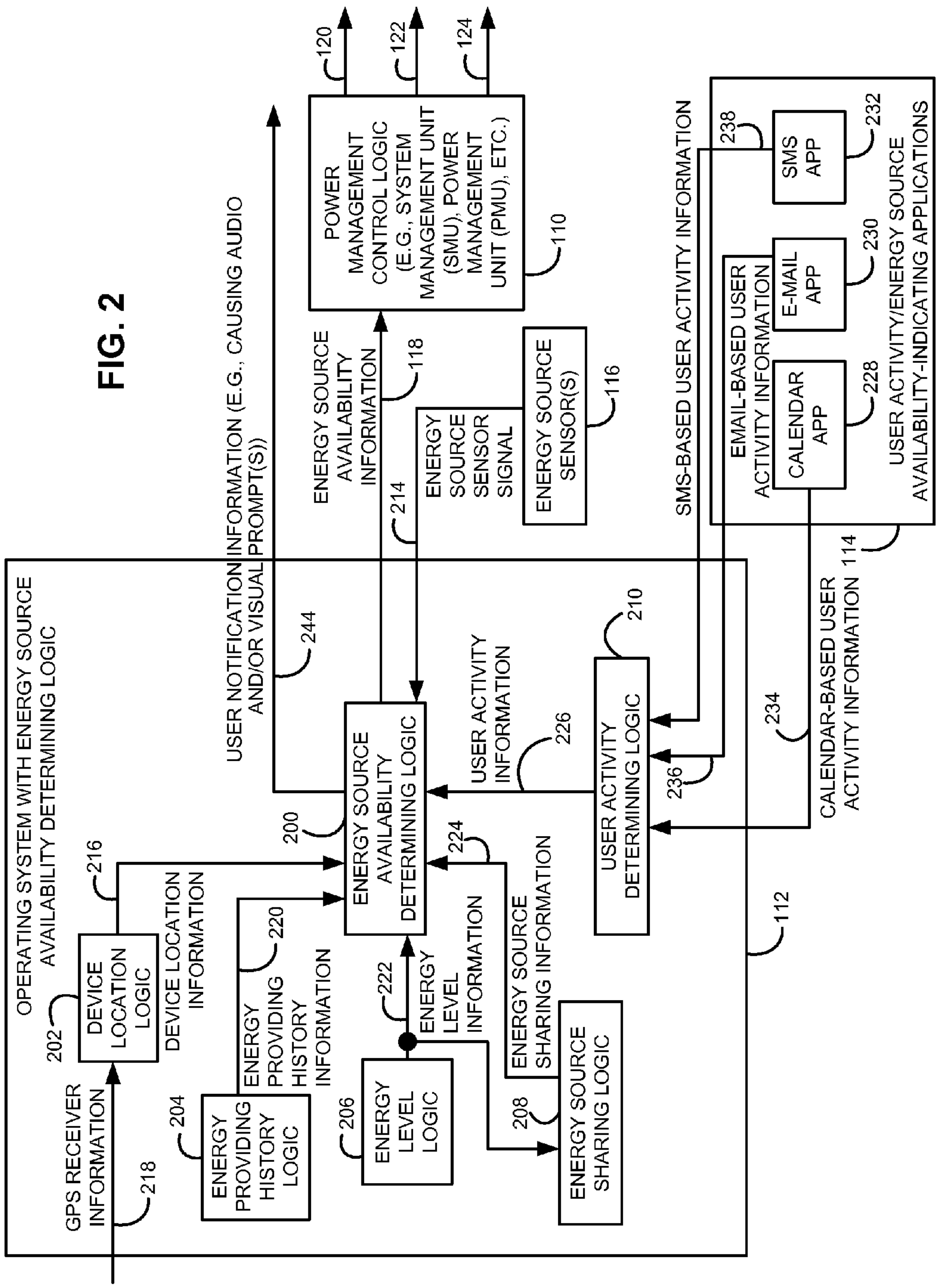

DISPLAY
130
PERIPHERALS
134
ENERGY SOURCE RECEPTACLE
136
PLUG
138
140
ENERGY SOURCE (E.G., CHARGER THAT PLUGS INTO WALL OUTLET)
MEMORY
OPERATING SYSTEM WITH ENERGY SOURCE AVAILABILITY DETERMINING LOGIC CODE
146
142
I/O DEVICES (E.G., 3G/4G TRANSCEIVER, Wi-Fi TRANSCEIVER, GPS RECEIVER, KEYPAD, TOUCH SCREEN, AUDIO INPUT/OUTPUT, STYLUS, ETC.)
144
128
ENERGY SOURCE SENSOR(S)
116
INTERFACE CIRCUIT
126
ADDITIONAL POWER MANAGEMENT CONTROL INFORMATION
102
124
120
FIRST PROCESSOR (E.G., CPU)
114
ENERGY SOURCE AVAILABILITY APPLICATION(S)
112
OPERATING SYSTEM WITH ENERGY SOURCE AVAILABILITY DETERMINING LOGIC
104
ENERGY SOURCE AVAILABILITY INFORMATION
118
FIRST PROCESSOR POWER MANAGEMENT CONTROL INFORMATION
POWER MANAGEMENT CONTROL LOGIC (E.G., SYSTEM MANAGEMENT UNIT (SMU), POWER MANAGEMENT UNIT (PMU), ETC.)
110
122
SECOND PROCESSOR POWER MANAGEMENT CONTROL INFORMATION
PROCESSOR SUBSYSTEM (E.G., APU)
108
MEMORY (E.G., ON-CHIP MEMORY)
146
OPERATING SYSTEM WITH ENERGY SOURCE AVAILABILITY DETERMINING LOGIC CODE
SECOND PROCESSOR (E.G., GPU)
106
100

FIG. 1

FIG. 2


OPERATING SYSTEM WITH ENERGY SOURCE AVAILABILITY DETERMINING LOGIC
112
GPS RECEIVER INFORMATION
218
DEVICE LOCATION LOGIC
202
DEVICE LOCATION INFORMATION
216
ENERGY PROVIDING HISTORY LOGIC
204
ENERGY PROVIDING HISTORY INFORMATION
220
ENERGY LEVEL LOGIC
206
ENERGY LEVEL INFORMATION
222
ENERGY SOURCE SHARING LOGIC
208
ENERGY SOURCE SHARING INFORMATION
224
ENERGY SOURCE AVAILABILITY DETERMINING LOGIC
200
USER ACTIVITY DETERMINING LOGIC
210
USER ACTIVITY INFORMATION
226
USER NOTIFICATION INFORMATION (E.G., CAUSING AUDIO AND/OR VISUAL PROMPT(S))
244
ENERGY SOURCE AVAILABILITY INFORMATION
118
ENERGY SOURCE SENSOR SIGNAL
214
ENERGY SOURCE SENSOR(S)
116
POWER MANAGEMENT CONTROL LOGIC (E.G., SYSTEM MANAGEMENT UNIT (SMU), POWER MANAGEMENT UNIT (PMU), ETC.)
110
120
122
124
SMS-BASED USER ACTIVITY INFORMATION
238
EMAIL-BASED USER ACTIVITY INFORMATION
236
CALENDAR-BASED USER ACTIVITY INFORMATION
234
CALENDAR APP
228
E-MAIL APP
230
SMS APP
232
USER ACTIVITY/ENERGY SOURCE AVAILABILITY-INDICATING APPLICATIONS
114

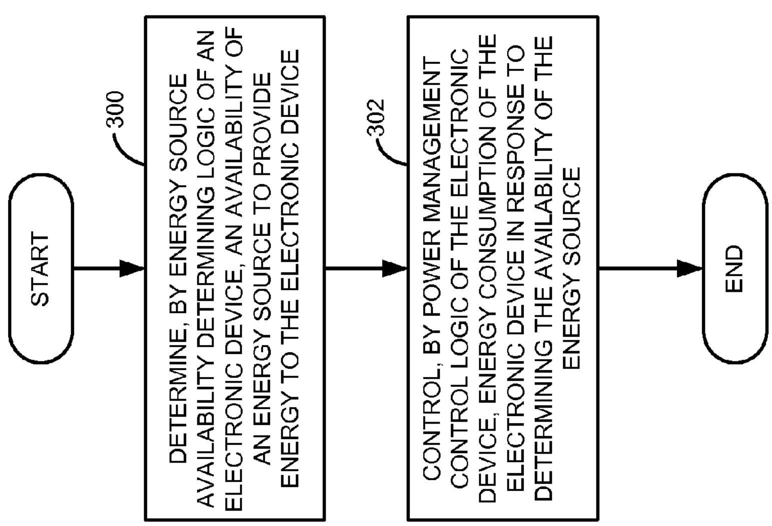


FIG. 3

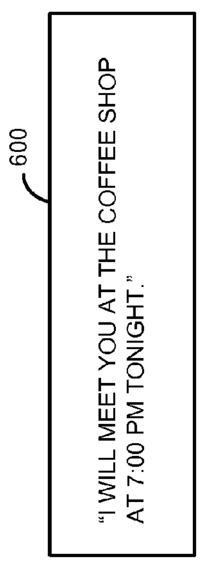


FIG. 6

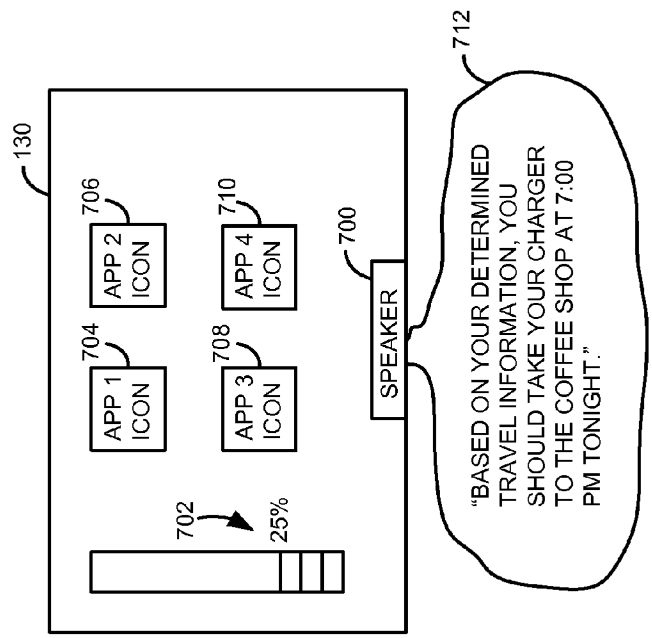


FIG. 7

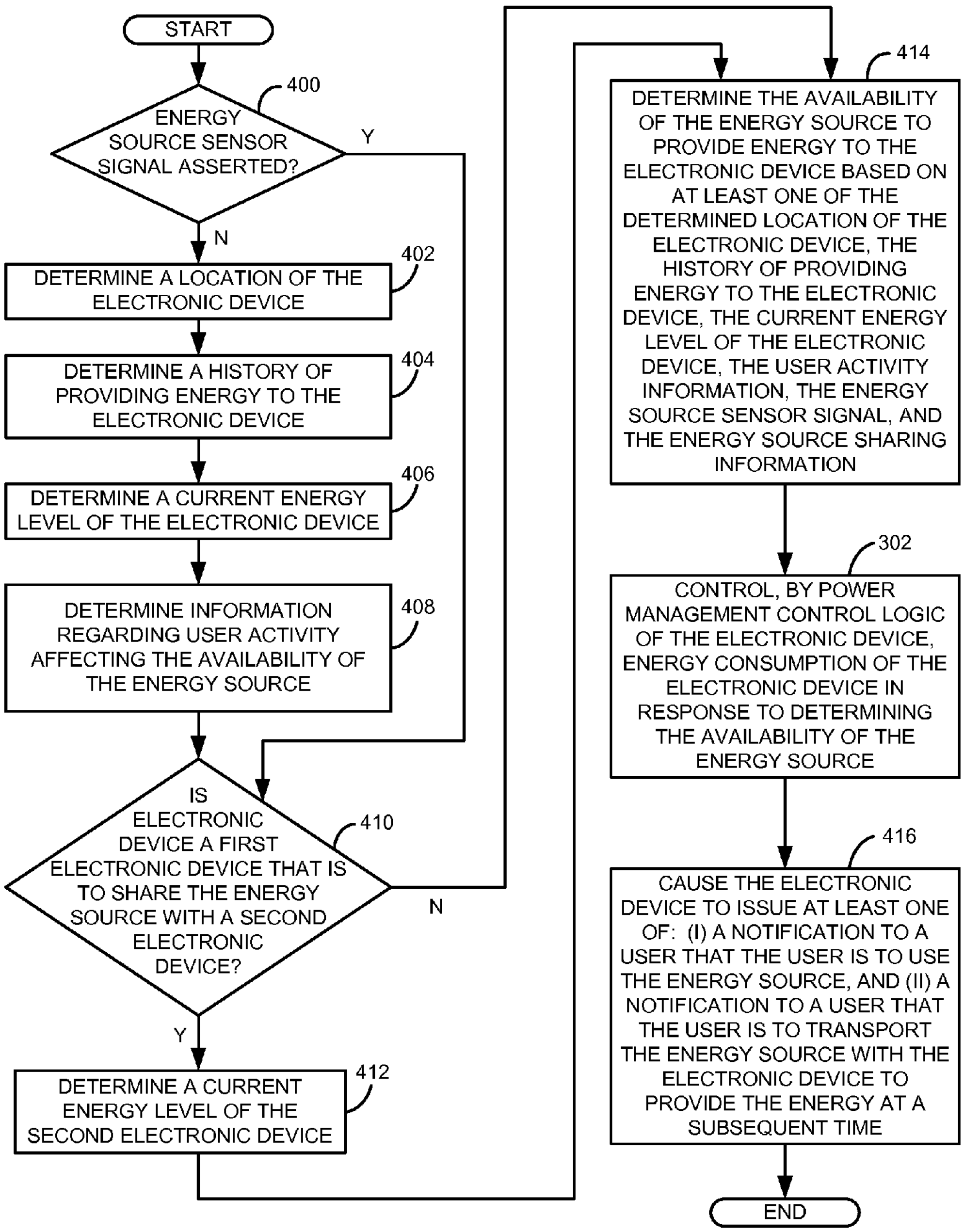

START
ENERGY SOURCE SENSOR SIGNAL ASSERTED?
400
Y
N
DETERMINE A LOCATION OF THE ELECTRONIC DEVICE
402
DETERMINE A HISTORY OF PROVIDING ENERGY TO THE ELECTRONIC DEVICE
404
DETERMINE A CURRENT ENERGY LEVEL OF THE ELECTRONIC DEVICE
406
DETERMINE INFORMATION REGARDING USER ACTIVITY AFFECTING THE AVAILABILITY OF THE ENERGY SOURCE
408
IS ELECTRONIC DEVICE A FIRST ELECTRONIC DEVICE THAT IS TO SHARE THE ENERGY SOURCE WITH A SECOND ELECTRONIC DEVICE?
410
N
Y
DETERMINE A CURRENT ENERGY LEVEL OF THE SECOND ELECTRONIC DEVICE
412
DETERMINE THE AVAILABILITY OF THE ENERGY SOURCE TO PROVIDE ENERGY TO THE ELECTRONIC DEVICE BASED ON AT LEAST ONE OF THE DETERMINED LOCATION OF THE ELECTRONIC DEVICE, THE HISTORY OF PROVIDING ENERGY TO THE ELECTRONIC DEVICE, THE CURRENT ENERGY LEVEL OF THE ELECTRONIC DEVICE, THE USER ACTIVITY INFORMATION, THE ENERGY SOURCE SENSOR SIGNAL, AND THE ENERGY SOURCE SHARING INFORMATION
414
CONTROL, BY POWER MANAGEMENT CONTROL LOGIC OF THE ELECTRONIC DEVICE, ENERGY CONSUMPTION OF THE ELECTRONIC DEVICE IN RESPONSE TO DETERMINING THE AVAILABILITY OF THE ENERGY SOURCE
302
CAUSE THE ELECTRONIC DEVICE TO ISSUE AT LEAST ONE OF: (I) A NOTIFICATION TO A USER THAT THE USER IS TO USE THE ENERGY SOURCE, AND (II) A NOTIFICATION TO A USER THAT THE USER IS TO TRANSPORT THE ENERGY SOURCE WITH THE ELECTRONIC DEVICE TO PROVIDE THE ENERGY AT A SUBSEQUENT TIME
416
END

FIG. 4

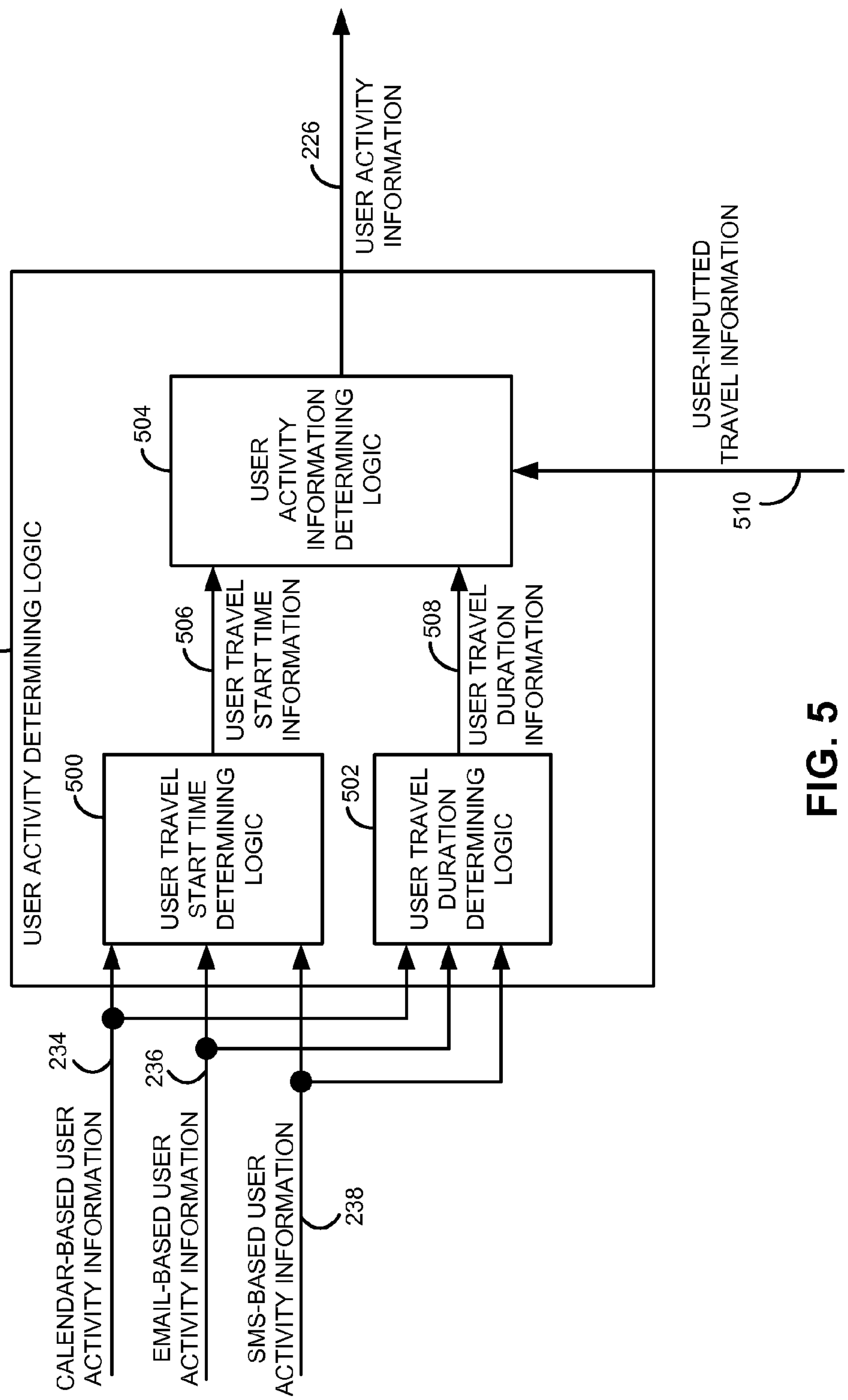

226
USER ACTIVITY INFORMATION
210
USER ACTIVITY DETERMINING LOGIC
504
USER ACTIVITY INFORMATION DETERMINING LOGIC
USER-INPUTTED TRAVEL INFORMATION
510
506
USER TRAVEL START TIME INFORMATION
508
USER TRAVEL DURATION INFORMATION
500
USER TRAVEL START TIME DETERMINING LOGIC
502
USER TRAVEL DURATION DETERMINING LOGIC
234
CALENDAR-BASED USER ACTIVITY INFORMATION
236
EMAIL-BASED USER ACTIVITY INFORMATION
238
SMS-BASED USER ACTIVITY INFORMATION

FIG. 5

CONTROLLING ENERGY CONSUMPTION OF AN ELECTRONIC DEVICE IN RESPONSE TO AVAILABILITY OF AN ENERGY SOURCE

BACKGROUND OF THE DISCLOSURE

The disclosure relates generally to electronic devices and more particularly to methods and apparatus for controlling energy consumption of an electronic device.

Runtime management solutions that control energy consumption are used in electronic devices in an attempt to assist in managing battery capacity of the electronic devices. Some existing solutions cause the electronic device to consume less energy when the battery level is low. Thus, an existing solution may reduce the activity of clients and/or applications running on the electronic device when the battery level drops below a certain percentage, with 100 percent corresponding to a fully-charged battery. This solution may turn off animations, vibrations of the electronic device that would otherwise occur in cases such as receipt of an incoming call, and dim the display screen of the electronic device. Another solution reduces or limits the performance state ("P-State") of a central processing unit (CPU) by limiting the CPU operating frequency and/or voltage in response to a low battery level or a thermal emergency.

Additional known solutions control activity initiated by a server. The server is made aware of an electronic device's residual battery level, estimated rate of energy consumption, and/or thermal information to make decisions regarding the features and/or quality of content to push to the electronic device. When the electronic device's battery level is low, advanced features can be disabled, quality of pushed content can be degraded, and/or the server may cause some computing functions to be shifted from the electronic device to the server. In some cases, the electronic device is also able to control shifting of computing functions to the server.

Reducing activity of clients and/or applications running on an electronic device, turning features off, reducing or limiting a P-state of an electronic device, disabling advanced features, and shifting computing operations to a server each degrade the experience of a user of the electronic device. While battery size may be increased and processing cores with lower power specifications, such as lower-power CPU cores, may be used in an effort to combat these problems, these approaches are unacceptable in devices with certain size and profile requirements and in devices that require the ability to support certain advanced applications and features.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments will be more readily understood in view of the following description when accompanied by the below figures and wherein like reference numerals represent like elements, wherein:

FIG. **1** is a functional block diagram illustrating an example electronic device including energy source availability determining logic and further illustrating a connectivity of the electronic device to an energy source;

FIG. **2** is a functional block diagram illustrating an example of further detail of an operating system with energy source availability determining logic and other aspects of the example electronic device of FIG. **1**;

FIG. **3** is a flowchart of an example method for controlling energy consumption of an electronic device;

FIG. **4** is a flowchart of an example method for controlling energy consumption of an electronic device and includes aspects of the method illustrated in FIG. **3** in more detail;

FIG. **5** is a functional block diagram illustrating an example implementation of user activity determining logic of the example electronic device of FIG. **1**;

FIG. **6** shows the text of an example SMS message which may be received by the electronic device and analyzed by the example user activity determining logic of FIG. **5**; and

FIG. **7** illustrates an example of a simplified front view of the electronic device, including a view of a display and a speaker that issues a notification to a user of the electronic device based on the electronic device receiving the example SMS message of FIG. **6**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Briefly, methods and apparatus for controlling energy consumption of an electronic device (e.g., a mobile or smart phone, a phablet, a tablet, a laptop computer, portable media player, or any other suitable device which requires replenishment of energy, such as any suitable battery-equipped device) are disclosed. In one embodiment, a method and an apparatus (e.g., a processor such as a CPU executing an operating system) control energy consumption of an electronic device based on an availability to provide energy to the electronic device (e.g., the expected availability to recharge the battery). The method and apparatus may determine the availability of an energy source (e.g., a battery charger) to provide the energy to the electronic device and may control the energy consumption of the electronic device before the energy is provided to the electronic device (e.g., before the electronic device is connected to the battery charger) in response to determining the availability of the energy source.

Among other advantages, for example, the disclosed methods and apparatus allow use of information regarding the availability of an energy source to control operation (e.g., energy consumption) of an electronic device. As a result, for example, whereas existing solutions reduce the activity of clients and/or applications running on the electronic device when the battery level drops below a certain percentage, the disclosed methods and apparatus may avoid doing so when it is determined that an energy source is or is expected to be readily available. Additionally, the need to make a server aware of, for example, an occurrence of a low battery situation may be avoided; the need for the server to reduce the quality of content provided to the electronic device may be avoided; and the need to shift computing functions from the electronic device to the server may be avoided. Other advantages will be recognized by one of ordinary skill in the art.

In one example, the electronic device may include at least one of an accelerated processing unit (APU), a central processing unit (CPU), a graphics processing unit (GPU), and display logic for a display. The methods and apparatus may control energy consumption of one or more of the APU, CPU, GPU, and/or display logic.

In another example, the methods and apparatus may determine the availability (e.g., expected availability) of the energy source to provide energy to the electronic device by determining a location of the electronic device, for example using a Global Positioning System (GPS) receiver of the electronic device, and by determining the availability of the energy source based on the determined location or a communicated signal (e.g., a signal transmitted, perhaps wirelessly, from a charging station to the electronic device). Additionally or alternatively, the methods and apparatus may determine the availability of the energy source to provide energy to the electronic device by determining a history of providing energy to the electronic device. For example, the methods and apparatus may determine a charging history of the electronic device, which may include indications of locations where the electronic device has been charged. The methods and apparatus may use the charging history and a current location of the electronic device to predict or determine the proximity of the electronic device to the energy source at a particular time in order to determine the availability of the energy source. For example, the methods and apparatus may compare the current location of the electronic device to the locations where the electronic device has been charged.

In yet another example, determining the availability of the energy source includes determining the availability based on at least one of a current energy level of the electronic device, user activity information indicative of a predicted or actual proximity of the electronic device to the energy source based on predicted activity of a user of the electronic device, and sharing information regarding sharing of the energy source between the electronic device and another electronic device. For example, with two electronic devices sharing the same charger, the electronic device with a lower amount of battery may be given first priority (e.g., allowed to use the charger first). At least one of the electronic devices may be involved in determining the order in which the electronic devices are to use the charger.

In another example, the electronic device includes an energy source sensor that detects proximity to the energy source. The methods and apparatus may determine the availability of the energy source to provide energy based on the detected proximity to the energy source.

In still another example, the methods and apparatus may control energy consumption of the electronic device in response to determining the availability of the energy source by at least one of controlling the electronic device to consume energy at a rate greater than a rate at which the electronic device is otherwise configured (e.g., without use of the methods and/or apparatus described herein) to consume energy when energy consumption is to be reduced, and controlling the electronic device to consume energy at a rate lesser than a rate at which the electronic device is otherwise configured to consume energy when energy consumption is to be reduced. For example, the electronic device may consume energy at a lesser rate if the methods and apparatus predict that the electronic device will not be in proximity to the charger and able to use the charger for a significant period of time. Conversely, the electronic device may consume energy at a greater rate if the methods and apparatus predict that the electronic device will be in proximity to the charger and able to use the charger in a relatively short period of time.

In another example, the methods and apparatus may cause the electronic device to issue at least one of: (i) a notification to a user of the electronic device that the user is to use the energy source to provide the energy to the electronic device, and (ii) a notification to the user that the user is to transport the energy source with the electronic device to provide the energy to the electronic device at a subsequent time.

Among other advantages, the methods and apparatus provide a way to determine an expected availability of an energy source to provide energy to an electronic device, and control energy consumption of the electronic device in response to determining the expected availability of the energy source. For example, it may be determined that the electronic device is close to, or is expected to soon be close to, an energy source that is available for use, so the disclosed methods and apparatus may not reduce the activity of clients and/or applications running on the electronic device. Depending upon the computational resources required, the disclosed methods and apparatus may even increase a rate of energy consumption of the electronic device in a situation where the electronic device is close to or is expected to soon be close to an available energy source. The methods and apparatus may also, for example, account for sharing of the energy source among more than one electronic device and control power consumption of each of the electronic devices that is to share the energy source. Other advantages of the subject matter disclosed herein will be recognized by those of ordinary skill in the art.

FIG. **1** is a functional block diagram illustrating an example electronic device **100** including energy source availability determining logic and further illustrating a connectivity of the electronic device **100** to an energy source as described below. The electronic device **100** may be any suitable electronic device such as, but not limited to, a mobile or smart phone, a phablet, a tablet, a laptop computer, portable media player, or any other suitable device which requires replenishment of energy, such as any suitable battery-equipped device, etc. In one embodiment, the energy source availability determining logic is implemented by a processor such as a CPU executing an operating system and the logic is implemented by the operating system. Thus, for ease of illustration and explanation, FIG. **1** shows the electronic device **100** as including an operating system with the energy source availability determining logic illustrated therein.

More particularly, as illustrated in FIG. **1**, the electronic device **100** includes a processor subsystem **102**, which includes a first processor **104** such as a CPU, a second processor **106** such as a graphics processing unit (GPU), a memory **108** such as an on-chip memory, and power management control logic **110**. The power management control logic may include, for example, a system management unit (SMU) or power management unit (PMU). The first processor **104** is illustrated as including an operating system with energy source availability determining logic **112**, and as including user activity/energy source availability-indicating applications **114** in communication with the operating system. The processor subsystem **102**, and in this example the first processor **104**, receives input from one or more energy source sensors **116**.

The operating system with energy source availability determining logic **112** determines an availability (e.g., expected availability) of an energy source, such as a battery charger, to provide energy to the electronic device **100** as further described below. The operating system with energy source availability determining logic **112** then provides energy source availability information **118** to the power management control logic **110**. The power management control logic **110**, in turn, controls energy consumption of the electronic device **100** before the energy is provided to the electronic device **100** (e.g., by a battery charger) in response to the operating system with energy source availability determining logic **112** determining the availability to provide energy to the electronic device **100**, where the availability may be indicated by the energy source availability information **118**. In particular, the power management control logic **110** may communicate first processor power management control information **120** to the first processor **104** and second processor power management control information **122** to the second processor **106**. The power management control logic **110** may also communicate additional power management control information **124** to an interface circuit **126** (e.g., a northbridge and/or a southbridge) to which the processor subsystem **102** is communicatively coupled in order to, for example, control power consumption of display logic that drives the output of a display. The power management control information **120**, **122**, and **124** may cause the first processor **104**, the second processor **106**, and additional components connected through the interface circuit **126** to adjust power consumption based on the availability to provide energy to the electronic device **100**.

The interface circuit **126** may connect the processor subsystem **102** to an expansion bus **128**, and the expansion bus **128** may further connect to, for example, a display **130**; one or more peripheral devices **134**; and an energy source receptacle **136** such as a port on the electronic device **100**. The energy receptacle may be connected by way of a suitable plug **138** to an energy source **140** (e.g., battery charger). The expansion bus **128** may also connect to an additional memory **142** and one or more input/output (I/O) devices **144**. The one or more I/O devices **144** may include, for example, one or more cellular transceivers such as a **3**G or **4**G transceiver; a Wi-Fi transceiver, a GPS receiver, a keypad, a touch screen, audio input/output devices, a stylus, and/or any other suitable input/output device(s).

In some embodiments, the processor subsystem **102** may be an accelerated processing unit (APU), which as known in the art includes one or more CPU cores and one or more GPU cores on the same die. Such an APU may be, for example, an APU as sold by Advanced Micro Devices, Inc. (AMD) of Sunnyvale, Calif. Alternatively, one or more of the first and second processors **104** and **106** may perform general-purpose computing on GPU (GPGPU), may include one or more digital signal processors (DSPs), one or more application-specific integrated circuits (ASICs), or the first and second processors **104** and **106** may be any suitable processors.

In some examples, the described energy source availability determining logic, and/or the power management control logic **110** and/or other logic described herein, may be implemented as software applications or "apps" by executing suitable instructions on, for example, the first processor **104** and/or the second processor **106**. In other examples, the described energy source availability determining logic, and/or the power management control logic **110**, and/or other logic described herein may be implemented by storing executable instructions on a computer readable storage medium, where the executable instructions are executable by one or more processors (e.g., the first processor **104** and/or the second processor **106**) to cause the one or more processors to perform the actions described herein. For example, executable instructions may be stored in the memory **108**, the additional memory **142**, or any suitable memory as operating system with energy source availability determining logic code **146**. The described energy source availability determining logic, and/or the power management control logic **110** and/or other logic described herein, may also be implemented in any other suitable manner such as but not limited to a hardware implementation or any suitable combination of the example implementations described above.

FIG. **2** is a functional block diagram illustrating an example of further detail of the operating system with energy source availability determining logic **112**, the user activity/energy source availability-indicating applications **114**, and the power management control logic **110**. Certain components of the example electronic device **100** of FIG. **1** are omitted from FIG. **2** for ease of illustration and explanation. The operating system with energy source availability determining logic **112** includes energy source availability determining logic **200**, device location logic **202**, energy providing history logic **204**, energy level logic **206**, energy source sharing logic **208**, and user activity determining logic **210**.

The energy source availability determining logic **200** may receive an energy source sensor signal **214** from the one or more energy source sensors **116**. In particular, the one or more energy source sensors **116** may detect proximity to an energy source such as the energy source **140** (e.g., a battery charger) and may provide the energy source sensor signal **214** accordingly to indicate the detected proximity. The energy source availability determining logic **200** may also receive device location information **216** from the device location logic **202**. The device location logic **202** may determine a current location of the device based on, for example, GPS receiver information **218** from a GPS receiver included in the one or more I/O devices **140**. The device location information **216** may include the current location of the electronic device **100** and, in some cases, a history of previous locations of the electronic device **100**.

The energy source availability determining logic **200** may also receive energy providing history information **220** from the energy providing history logic **204**. The energy providing history information **220** may include, for example, a record of times at which the electronic device **100** received energy from the energy source **140** and, if desired, other energy sources. The energy source availability determining logic **200** may additionally receive energy level information **222** from the energy level logic **206** indicating, for example, a current energy level (e.g., percentage battery level) of the electronic device **100**. Still further, the energy source availability determining logic **200** may receive energy source sharing information **224** from the energy source sharing logic **208**, where the energy source sharing information **224** may include, for example, information regarding one or more additional electronic devices with which the electronic device **100** is to share access to the energy source **140** and an order in which the energy source **140** is to provide energy to the first electronic device **100** and the one or more additional electronic devices (not shown, but which may in some examples be configured similarly to the electronic device **100**).

For example, the energy source sharing information **224** may include information indicative of a current energy level of a second electronic device, which information may be obtained from the second electronic device via, for example, a cellular network, the Internet and/or one or more cloud computing networks, etc. The energy source sharing information **224** may also include information as to which of the first electronic device **100** and the second electronic device is to manage sharing of the energy source **140**. In any event, the electronic device with a lower current energy level may be permitted to use the energy source **140** first. Accordingly, for example, when the current energy level of the second electronic device is higher than a current energy level of the first electronic device **100**, the energy source sharing information **224** may indicate this situation to the energy source availability determining logic **200**.

The energy source availability determining logic **200** may then generate the energy source availability information **118** to include an indication that energy consumption of the electronic device **100** is to be controlled by the power management control logic **110** so that the first electronic device **100** consumes energy at a rate less than a rate at which the first electronic device **100** would otherwise (e.g., in the absence of the second electronic device sharing the energy source **140**) consume energy before the energy is provided to the first electronic device by way of the energy source **140**. When the second electronic device has finished using the energy source **140** (e.g., by reaching a particular percentage battery level), the energy source availability determining logic **200** may then generate the energy source availability information **118** by accounting for the energy source **140** no longer needing to be shared.

The energy source availability determining logic **200** may also receive user activity information **226** from the user activity determining logic **210**. The user activity information **226** may be indicative of a predicted proximity of the electronic device **100** to the energy source **140** as determined based on predicted activity of a user of the electronic device **100**. For example, the user activity determining logic **210** may generate the user activity information **226** based on information from the user activity/energy source availability-indicating applications **114**. In one embodiment, the user activity/energy source availability-indicating applications **114** may include a calendar application or "app" **228**, an e-mail app **230**, and a Short Message Service (SMS) app **232**. The user activity determining logic **210** may receive calendar-based user activity information **234**; email-based user activity information **236**; and SMS-based user activity information **238** from the apps **228**, **230**, and **232**, respectively. The user activity determining logic **210** may analyze the information **234**, **236**, and **238** as further described below to provide the user activity information **226** to the energy source availability determining logic **200**.

As discussed above, the energy level information **222** may additionally be provided to the energy source sharing logic **208** as shown in FIG. **2** so that the energy source sharing logic **208** may generate energy source sharing information **224** that accounts for the energy level of the first electronic device **100**.

The energy source availability determining logic **200** may analyze one or more of the energy source sensor signal **214**, the device location information **216**, the energy providing history information **220**, the energy level information **222**, the energy source sharing information **224**, and the user activity information **226** in any suitable manner in order to generate the energy source availability information **118**. The energy source availability information **118** indicates the availability of an energy source (e.g., the energy source **140**) to provide energy to the electronic device **100** based on, for example, the information analyzed by the energy source availability determining logic **200**. It will be appreciated that, based on the information that may be analyzed to determine the energy source availability information **118**, the availability to provide energy as indicated by the energy source availability information **118** may include an indication of how energy consumption of the electronic device **100** is to be controlled by the power management control logic **110**.

Additionally, by analyzing one or more of the signals and/or information discussed above, the energy source availability determining logic **200** may also generate user notification information **244**. As further discussed below, the user notification information **244** may cause, for example, the display **130** and/or one or more of the I/O devices **140** to issue an audio and/or visual prompt(s) to the user of the electronic device **100** to, for example, provide energy to the electronic device **100**.

With continued reference to FIG. **2** and turning also to FIG. **3**, FIG. **3** is a flowchart of an example method for controlling energy consumption of an electronic device. The method illustrated in FIG. **3**, and each of the example methods described herein, may be carried out by one or more suitably programmed controllers or processors executing software (e.g., by the first processor **104** executing the operating system with energy source availability determining logic **112** and by the power management control logic **110** when the power management control logic **110** is implemented as a controller or processor executing software). The method may also be embodied in hardware or a combination of hardware and hardware executing software. Suitable hardware may include one or more application specific integrated circuits (ASICs), state machines, field programmable gate arrays (FPGAs), digital signal processors (DSPs), and/or other suitable hardware. Although the method(s) is/are described with reference to the illustrated flowcharts (e.g., in FIG. **3**), it will be appreciated that many other ways of performing the acts associated with the method(s) may be used. For example, the order of some operations may be changed, and some of the operations described may be optional. Additionally, while the method(s) may be described with reference to the electronic device **100**, it will be appreciated that the method(s) may be implemented by other devices as well, and that the electronic device **100** may implement other methods.

As shown in FIG. **3**, the method begins at block **300** when energy source availability determining logic, such as logic included in an operating system as discussed with reference to FIGS. **1** and **2**, determines an availability of an energy source, such as the energy source **140**, to provide energy to an electronic device, such as to the electronic device **100** by way of the energy source receptacle **136** and the plug **138**.

As shown in block **302**, power management control logic of the electronic device, such as the power management control logic **110**, then controls energy consumption of the electronic device **100** in response to determining the availability of the energy source (e.g., in response to the determination in block **300**).

With reference to FIG. **4**, FIG. **4** is a flowchart of another example method for controlling energy consumption of an electronic device and includes aspects of the method illustrated in FIG. **3** in more detail. As shown in block **400**, the method may include determining whether the energy source sensor signal **214** is asserted, which may indicate that the energy source sensor(s) **116** have detected proximity to the energy source **140**. If the energy source sensor signal **214** is not asserted, flow may proceed to block **402**. If the energy source sensor signal is asserted, flow may proceed to block **410**.

As shown in block **402**, the method may include determining a location of the electronic device **100**, such as by the device location logic **202** analyzing the GPS receiver information **218** to determine the device location information **216**. The actions described with respect to block **402** may also include, for example, determining how often and/or particular times at which the electronic device **100** has previously been at the determined location. As another example, the actions described with respect to block **402** may also include utilizing map data obtained based on analyzing the GPS receiver information **218** to determine whether the location of the electronic device **100** is within a residence or other area in which the electronic device **100** is expected to have greater (or lesser, depending upon the detected location in conjunction with the map data) access to an energy source such as the energy source **140**.

In some examples, the actions described with respect to block **402** may also or alternatively include analyzing the GPS receiver information **218** to determine one or more travel parameters of the electronic device **100**, such as, for example, a current direction in which the electronic device **100** is traveling and a current speed at which the electronic device **100** is traveling. Additionally, in some examples, the actions described with respect to block **402** may include analyzing information regarding a known location of an energy source, such as the energy source **140** (e.g., information regarding a location at which the electronic device **100** was previously plugged into the energy source **140** or previously detected the energy source **140** using the energy source sensor(s) **116**). The information regarding the known location of the energy source may be analyzed in conjunction with the determined travel parameter(s) of the electronic device **100** to predict when the electronic device **100** is expected to be in proximity to the energy source **140** (e.g., close enough to receive energy from the energy source **140** immediately or within a small amount of time, such as on the order of, for example, tens of seconds needed to connect the energy source receptacle **136** to the energy source **140**).

In another example, the actions described with respect to block **402** may include determining that the location of the electronic device **100** already corresponds to the known location of the energy source **140** (e.g., is already in proximity to the energy source **140**) so that the electronic device **100** can receive energy from the energy source **140** immediately or within a small amount of time as discussed above. These determinations may be used in eventually determining the expected availability of the energy source **140** to provide energy to the electronic device **100**.

As shown in block **404**, the method may further include determining a history of providing energy to the electronic device **100**. For example, the energy source availability determining logic **200** may obtain the energy providing history information **220** from the energy providing history logic **204**. As noted above, the energy providing history information **220** may include a record of times at which the electronic device **100** received energy from the energy source **140** to be used in the eventual determination (e.g., prediction) of the expected availability of the energy source **140**. In some examples, the energy source availability determining logic **200** may utilize the energy providing history information **220** in combination with the device location information **216**, such as in combination with particular times at which the electronic device **100** has previously been at the determined location of the electronic device **100**, to predict a proximity of the electronic device **100** to the energy source **140** at a particular time.

Determining the history of providing energy to the electronic device **100** may also include determining or maintaining a record of times at which the electronic device **100** received energy from other energy sources (not shown), e.g., energy sources other than the energy source **140**. The energy source availability determining logic **200** may then utilize the energy providing history information **220**, which may include these additional records, in combination with the device location information **216** to predict a proximity of the electronic device **100** to any of a plurality of energy sources at a particular time.

As shown in block **406**, the method may further include determining a current energy level of the electronic device **100**. For example, the energy level logic **206** may provide the energy level information **222**, which may be information indicating a level of charge of a battery of the electronic device **100**, to the energy source availability determining logic **200**.

As shown in block **408**, the method may further include determining (e.g., predicting) information regarding user activity affecting the availability of the energy source. For example, the user activity determining logic **210** may provide the user activity information **226** to the energy source availability determining logic **200**.

From block **408**, flow may proceed to block **410**. As noted above with respect to block **400**, if it is determined that the energy source sensor signal **214** is asserted, flow may also proceed to block **410**. As shown in block **410**, the method may include determining whether the electronic device **100** is a first electronic device that is to share the energy source **140** with a second electronic device. For example, the electronic device **100** may receive a signal periodically transmitted from a second electronic device indicating that the second electronic device needs to receive energy from the same energy source (e.g., the energy source **140**) as an energy source indicated by the location of the first electronic device (e.g., as determined using the GPS receiver information **218**).

In such a situation, it is determined in block **410** that the electronic device **100** is a first electronic device that is to share the energy source **140** with a second electronic device, and flow proceeds to block **412**. If it is determined in block **410** that the electronic device **100** is not a first electronic device that is to share the energy source **140** with a second electronic device, flow proceeds to block **414**. It will be appreciated that additional electronic devices may also transit similar information indicating a need to receive energy from a nearby energy source and that additional electronic devices may also share the energy source **140** with the first electronic device **100**.

As shown in block **412**, the method may include determining a current energy level of the second electronic device. In some embodiments, the energy source sharing information **224** may reflect the current energy level of the second electronic device, as discussed above.

As shown in block **414**, the method may include determining the availability (e.g., expected availability) of the energy source **140** to provide energy to the electronic device **100** based on at least one of the determined location of the electronic device **100**, the history of providing energy to the electronic device **100**, the current energy level of the electronic device **100**, the user activity information **226** indicative of a predicted proximity of the electronic device **100** to the energy source as determined based on predicted activity of a user of the electronic device **100**, the energy source sensor signal **214** when applicable, and when applicable (e.g., when it is determined in block **410** that the electronic device **100** is to share the energy source **140**), the energy source sharing information **224**. Because flow may proceed from block **400** to block **410** when the energy source sensor signal **214** is asserted, determining the availability (e.g., expected availability) of the energy source **140** to provide energy to the electronic device **100** may, if desired, be more narrowly based on sensor-detected proximity to the energy source **140** and considerations such as the energy source sensor signal **214** and, when applicable, sharing of the energy source **140** with a second electronic device (e.g., block **410**) and the current energy level of the second electronic device (e.g., block **412**).

As shown in block **302** and as discussed with reference to FIG. **3**, the method may also include controlling, by the power management control logic **110**, energy consumption of the electronic device **100** in response to determining the availability of the energy source **140**.

For example, the expected availability to provide energy to the electronic device **100** may indicate that energy consumption is to be controlled so that the electronic device **100** consumes energy at a rate greater than a rate at which the electronic device **100** is otherwise (e.g., without having determined the expected availability to provide energy to the electronic device **100** as described herein) configured to consume energy when energy consumption is to be reduced. For example, the electronic device **100** may otherwise be configured to reduce its rate of energy consumption by a certain amount when an amount of battery charge remaining reaches, for example, 20 percent of the capacity of the battery. However, the expected availability to provide energy to the electronic device **100** may indicate in this example situation that the rate of energy consumption of the electronic device **100** can be reduced by a lesser amount and/or more gradually as compared to a manner in which the electronic device **100** is otherwise configured to reduce the rate of its energy consumption.

In some cases, the expected availability to provide energy to the electronic device **100** may indicate that the rate of energy consumption of the electronic device **100** can be maintained or even increased if, for example, applications currently executing on the electronic device **100** require increased energy consumption for optimal performance and the expected availability to provide energy indicates that maintaining or increasing the rate of energy consumption will not cause the battery charge to run out before the electronic device **100** is expected to be able to be connected to the energy source **140**.

In the foregoing situations, the energy source availability information **118** may indicate to the power management control logic **110** that the rate of energy consumption may be reduced by a lesser amount and/or more gradually, maintained, or increased, as the case may be, and the power management control logic **110** may generate the power management control information **120**, **122**, and **124** accordingly.

With continued reference to block **302**, in other situations, the expected availability to provide energy to the electronic device **100** may indicate that energy consumption is to be controlled so that the electronic device **100** consumes energy at a rate less than the rate at which the electronic device **100** is otherwise configured to consume energy when energy consumption is to be reduced, and/or so that the electronic device **100** reduces its rate of energy consumption sooner than the electronic device **100** is otherwise configured to do so. For example, the expected availability to provide energy may indicate that, even with the configured reduction in the rate of energy consumption, energy will not be able to be provided to the electronic device **100** before the battery charge runs out (e.g., based on the user activity information **226** or any suitable input to the energy source availability determining logic **200**).

In this situation, the energy source availability information **118** may indicate to the power management control logic **110** that the rate of energy consumption is to be reduced by a greater amount, and/or sooner, than an amount and/or time by or at which the electronic device **100** is otherwise configured to reduce energy consumption. The power management control logic **110** may then generate the power management control information **120**, **122**, and **124** accordingly.

As shown in block **416**, the method may also include causing the electronic device **100** to issue at least one of: (i) a notification to a user of the electronic device **100** that the user is to use an energy source (e.g., the energy source **140**) to provide the energy to the electronic device **100**, and (ii) a notification to a user of the electronic device **100** that the user is to transport an energy source (e.g., the energy source **140**), and in some examples the plug **138**, with the electronic device **100** to provide the energy to the electronic device **100** at a subsequent time. For example, the energy source availability determining logic **200** may generate user notification information **244** to cause audio or visual prompts based on the expected availability to provide energy to the electronic device **100**, thereby causing, for example, the display **130** and or one or more of the I/O devices **140** to issue an audio and/or visual notification(s) to the user. More particularly, a notification that the user is to use the energy source **140** or is to transport the energy source **140** to provide the energy at a subsequent time may be based on, for example, the user activity information **226** which may be indicative of a future location of the electronic device **100** as predicted based on predicted activity of a user of the electronic device **100**.

FIG. **5** is a functional block diagram illustrating an example implementation of the user activity determining logic **210**. The user activity determining logic **210** may include user travel start time determining logic **500**, user travel duration determining logic **502**, and user activity information determining logic **504**. As shown in FIG. **5**, each of the user travel start time determining logic **500** and the user travel duration determining logic **502** may receive the calendar-based user activity information **234**, the email-based user activity information **236**, and the SMS-based user activity information **238**, which may include information regarding the contents of calendar appointments, e-mail messages, and SMS messages, respectively.

The user travel start time determining logic **500** may include any suitable logic to analyze contents of, for example, calendar appointments on the calendar application **228** as indicated in the calendar-based user activity information **234**, and/or similar e-mail and SMS items as indicated in the information **236** and **238**, respectively, to determine a user travel start time. For example, the user travel start time determining logic **500** may scan calendar appointments to determine the start time of the appointments, and/or may scan e-mail and SMS items for key words and/or phrases such as "meet at" and/or, for example, the words "meet" and "at" within a particular (e.g., configurable) number of words of one another. The user travel start time determining logic **500** may then scan the e-mail and SMS items for an associated time to determine the user travel start time.

Of course, key words synonymous with "meet" and "at" may also be searched, and the user travel start time determining logic **500** may also or alternatively be configured to scan the calendar-based user activity information **234**, the email-based user activity information **236**, and the SMS-based user activity information **238** in any other suitable manner. The user travel start time determining logic **500** may generate user travel start time information **506** indicating a determined (e.g., predicted) start time of travel of a user of the electronic device **100** and may provide the user travel start time information **506** to the user activity information determining logic **504**.

The user travel duration determining logic **502** may include any suitable logic to analyze contents of, for example, calendar appointments on the calendar application **228** as indicated in the calendar-based user activity information **234**, and/or similar e-mail and SMS items as indicated in the information **236** and **238**, respectively, to determine a user travel start duration. For example, the user travel duration determining logic **502** may scan calendar appointments to determine the length of appointments, and/or may scan e-mail and SMS items for key words and/or phrases indicating a length of travel of a user. As just one example, the user travel duration determining logic **502** may scan e-mail and SMS items for information such as a flight departure and flight arrival time indicated in an e-mailed itinerary, an amount of time between two particular times included in an e-mail or SMS item with a nearby keyword such as "from" suggesting that the particular times are a start time and an end time of an event, etc.

The user travel duration determining logic **502** may also or alternatively be configured to scan the calendar-based user activity information **234**, the email-based user activity information **236**, and the SMS-based user activity information **238** in any other suitable manner. The user travel duration determining logic **502** may generate user travel duration information **508** indicating a determined (e.g., predicted) duration of travel of a user of the electronic device **100** and may provide the user travel duration information **508** to the user activity information determining logic **504**.

The user activity information determining logic **504** may then analyze the user travel start time information **506** and the user travel duration information **508** to determine the user activity information **226**. In this manner, proceeding under the assumption that the user will bring the electronic device **100** with him or her during travel, the user activity information **226** may indicate a predicted proximity of the electronic device **100** to the energy source **140** as determined based on predicted activity of the user. For example, the user activity information **226** may indicate that the electronic device **100** is predicted to be at a location away from the energy source **140** starting at a time indicated by the user travel start time information **506** and extending for a duration indicated by the user travel duration information **508** unless the user transports the energy source **140** with the electronic device **100** during travel.

In some embodiments, the user activity information determining logic **504** may receive user-inputted travel information **510**. Where the user-inputted travel information **510** specifies the travel start time and/or duration, the user-inputted travel information **510** may override the user travel start time information **506** and/or the user travel duration information **508** accordingly in the analysis by the user activity information determining logic **508**.

FIG. **6** shows the text of an example SMS message **600** which may be received by the electronic device **100** and analyzed by the user activity determining logic **210**. The example SMS message **600** reads "I will meet you at the coffee shop at 7:00 pm tonight." FIG. **7** illustrates an example of a simplified front view of the electronic device, including a view of the display **130** and a speaker **700** that, as discussed below, issues a notification to a user of the electronic device **100** based on the electronic device **100** receiving the SMS message **600** of FIG. **6**. The speaker **700** may be one of the I/O devices **144** shown and described with respect to FIG. **1**.

As illustrated in FIG. **7**, the display **130** shows a battery level icon **702** indicating that approximately 25 percent battery charge remains. The display **130** also shows icons that may be used to access various applications ("apps") executing or executable on the electronic device **100**. For example, the display **130** may show a first application icon **704** for a first app, a second application icon **706** for a second app, a third application icon **708** for a third app, and a fourth application icon **710** for a fourth app.

As shown in FIG. **7**, the speaker **700** issues a notification in the form of an audio prompt **712** to a user of the electronic device, where the audio prompt **712** may include an audio message saying "Based on your determined travel information, you should take your charger to the coffee shop at 7:00 pm tonight." In this example, the user travel duration determining logic **502** in the example of FIG. **5** may be configured to analyze the SMS message **600** and infer from the key words "coffee shop" that the duration of travel will be at least several hours. The user activity determining logic **210** may then generate the user activity information **226**. The energy source availability determining logic **200** may generate the user notification information **244** to cause issuance of the audio prompt **712** based on, for example, the user activity information and the energy level information **222**. For example, the energy source availability determining logic **200** may determine that the user activity information **226** indicates a prediction that the electronic device **100** will be away from the energy source **140** for a sufficiently long time based on the energy level information **222** (indicating the approximately 25 percent battery level) that the electronic device **100** will run out of energy unless the user takes the energy source **140** (e.g., battery charger) with him or her to the coffee shop.

Among other advantages, for example, one or more of the above embodiments allow a way to determine an expected availability of an energy source to provide energy to an electronic device, and control energy consumption of the electronic device in response to determining the expected availability of the energy source. The expected availability of the energy source to provide energy to the electronic device may be based on any of one or more suitable and/or desired factors, such as information regarding a location of the electronic device, information regarding a history of providing energy to the electronic device, current energy level information regarding the electronic device, information regarding sharing of the energy source between the electronic device and another electronic device or devices, an energy source sensor signal, and user activity information, for example. Other advantages will be recognized by those of ordinary skill in the art.

The foregoing description has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the exemplary embodiments disclosed. Many modifications and variations are possible in light of the above teachings. It is intended that the scope of the invention be limited not by this detailed description of examples, but rather by the claims appended hereto.

What is claimed is:

1. A method for controlling energy consumption of an electronic device, the method comprising:

determining, by energy source availability determining logic of the electronic device, an availability of an energy source to provide energy to the electronic device; and

controlling, by power management control logic of the electronic device, energy consumption of the electronic device in response to determining the availability of the energy source, wherein the electronic device is a first electronic device, wherein the method comprises determining a current energy level of a second electronic device to which the energy source is to provide energy, and wherein determining the availability of the energy source to provide energy to the first electronic device is based on the current energy level of the second electronic device, wherein determining the availability of the energy source to provide energy to the electronic device comprises:

determining a location of the second electronic device; and

determining the availability of the energy source based on the determined location of the second electronic device.

2. The method of claim **1**, wherein determining the availability of the energy source to provide energy to the electronic device comprises:

determining a location of the electronic device; and

determining the availability of the energy source based on the determined location of the electronic device.

3. The method of claim **1**, wherein determining the availability of the energy source comprises determining the availability based on at least one of: (i) user activity information indicative of a predicted proximity of the electronic device to the energy source as determined based on predicted activity of a user of the electronic device, and (ii) sharing information regarding sharing of the energy source between the first electronic device and the second electronic device.

4. The method of claim **1**, wherein when the current energy level of the second electronic device is higher than a current energy level of the first electronic device, controlling the energy consumption of the first electronic device comprises controlling the first electronic device to consume energy at a rate less than a rate at which the first electronic device would otherwise consume energy before the energy is provided to the first electronic device.

5. The method of claim 1, wherein controlling the energy consumption of the electronic device in response to determining the availability of the energy source comprises at least one of: (i) controlling the electronic device to consume energy at a rate greater than a rate at which the electronic device is otherwise configured to consume energy when energy consumption of the electronic device is to be reduced, and (ii) controlling the electronic device to consume energy at a rate less than the rate at which the electronic device is otherwise configured to consume energy when energy consumption of the electronic device is to be reduced.

6. The method of claim 1, comprising issuing at least one of: (i) a notification to a user of the electronic device that the user is to use the energy source to provide the energy to the electronic device, and (ii) a notification to a user of the electronic device that the user is to transport the energy source with the electronic device to provide the energy to the electronic device at a subsequent time.

7. An apparatus for controlling energy consumption of an electronic device, the apparatus comprising:

energy source availability determining logic operative to determine an availability of an energy source to provide energy to the electronic device; and

power management control logic operative to control energy consumption of the electronic device in response to the energy source availability determining logic determining the availability of the energy source, wherein the electronic device is a first electronic device, wherein the energy source availability determining logic is operative to determine a current energy level of a second electronic device to which the energy source is to provide energy, and wherein determining the availability of the energy source to provide energy to the first electronic device is based on the current energy level of the second electronic device, wherein the energy source availability determining logic is operative to:

determine a location of the second electronic device; and

determine the availability of the energy source based on the determined location of the second electronic device.

8. The apparatus of claim 7, wherein the energy source availability determining logic is operative to:

determine a location of the electronic device; and

determine the availability of the energy source based on the determined location of the electronic device.

9. The apparatus of claim 7, wherein the energy source availability determining logic is operative to:

predict a proximity of the electronic device to the energy source at a particular time; and

determine the availability of the energy source based on the predicted proximity of the electronic device to the energy source at the particular time.

10. The apparatus of claim 9, wherein the power management control logic is operative to control the energy consumption of the electronic device in response to the energy source availability determining logic determining the availability of the energy source by at least one of: (i) controlling the electronic device to consume energy at a rate greater than a rate at which the electronic device is otherwise configured to consume energy when energy consumption of the electronic device is to be reduced, and (ii) controlling the electronic device to consume energy at a rate less than the rate at which the electronic device is otherwise configured to consume energy when energy consumption of the electronic device is to be reduced.

11. The apparatus of claim 7 operable to receive an indication of a detected proximity to the energy source,

wherein the energy source availability determining logic is operative to determine the availability of the energy source based on the received indication of the detected proximity to the energy source.

12. The apparatus of claim 7, wherein the energy source availability determining logic is comprised of a processor and memory containing executable instructions that, when executed by the processor, cause the processor to determine the availability of the energy source to provide energy to the electronic device.

13. The apparatus of claim 7, comprising at least one of an accelerated processing unit (APU), a central processing unit (CPU), a graphics processing unit (GPU), and display logic operatively coupled to a display, wherein the power management control logic is operative to control the energy consumption of the electronic device in response to the energy source availability determining logic determining the availability of the energy source by controlling energy consumption of one or more of the at least one of the APU, the CPU, the GPU, and the display logic.

14. A non-transitory computer readable storage medium comprising executable instructions that when executed by one or more processors cause the one or more processors to:

determine an availability of an energy source to provide energy to an electronic device;

determine a current energy level of a second electronic device to which the energy source is to provide energy; and

provide energy source availability information indicative of the availability of an energy source to power management control logic of the electronic device whereby an energy consumption of the electronic device is controlled in response to the one or more processors determining the availability of the energy source, wherein the electronic device is a first electronic device, and wherein determining the availability of the energy source to provide energy to the first electronic device is based on the current energy level of the second electronic device, wherein determining the availability of the energy source to provide energy to the electronic device comprises:

determining a location of the second electronic device; and

determining the availability of the energy source based on the determined location of the second electronic device.

15. The non-transitory computer readable storage medium of claim 14, comprising executable instructions that when executed by the one or more processors cause the one or more processors to:

determine at least one of a location of the electronic device and a history of providing energy to the electronic device; and

determine the availability of the energy source based on the at least one of the determined location of the electronic device and the determined history of providing energy to the electronic device.

16. The non-transitory computer readable storage medium of claim 14, comprising executable instructions that when executed by the one or more processors cause the one or more processors to determine the availability of the energy source based on at least one of: (i) user activity information indicative of a predicted proximity of the electronic device to the energy source as determined based on predicted activity of a user of the electronic device, and (ii) sharing information regarding sharing of the energy source between the first electronic device and the second electronic device.

17. The non-transitory computer readable storage medium of claim **14**, comprising executable instructions that when executed by the one or more processors cause the one or more processors to:

obtain information from the second electronic device indicative of a current energy level of the second electronic device; and

determine an order in which the energy source is to provide energy to the first electronic device and the second electronic device based on a current energy level of the first electronic device and the current energy level of the second electronic device.

18. The non-transitory computer readable storage medium of claim **14**, comprising executable instructions that when executed by the one or more processors cause the one or more processors to cause the electronic device to issue at least one of: (i) a notification to a user of the electronic device that the user is to use the energy source to provide the energy to the electronic device, and (ii) a notification to a user of the electronic device that the user is to transport the energy source with the electronic device to provide the energy to the electronic device at a subsequent time.

19. The non-transitory computer readable storage medium of claim **14**, comprising executable instructions that when executed by the one or more processors cause the one or more processors to:

detect proximity to the energy source based on a signal from an energy source sensor of the electronic device; and

determine the availability of the energy source based on the detected proximity to the energy source.

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